A surface plasmon tunable color filter has being developed in JPL. It can replace the color wheel for projection displays, and it can be employed for a monochrome liquid crystal panel to generate a full color image.

The surface plasmon has been studied since the 1960's. It can be described as a collective oscillation in electron density at the interface of a metal and a dielectric. At surface plasmon resonance, the reflected light vanishes. This resonance is referred to as attenuated total reflection, and is dependent upon the dielectric constant of both the metal and the dielectric. If an electro-optical (EO) material is used as the dielectric and a voltage is applied to change the surface plasmon resonance condition, the reflected light can be modulated[1]. A surface plasmon last.l light modulator with a contrast ratio greater than 100:1 has been reported[2].

If we consider the surface plasmon light modulator in the frequency space, the photons at surface plasmon resonance will be absorbed and the photons out of the resonance will be totally reflected. If a voltage is applied on the EO material, the index of refraction of the 110 mate.l-ial will change, the surface plasmon resonance frequency will change, therefore the reflection spectrum can be controlled by the applied voltage, and an electronically tunable color filter is formed[3].

The experiment setup of surface plasmon tunable filter is shown in Fig. 1. Here a 50 nm silver was used as the metal film and a 4μ liquid crystal layer was used as the 110 material. When a p-polarized white light is incident on the metal/liquid crystal interface through the coupling prism, a surface plasmon wave can be excited, the photons in the surface plasmon resonance will be taken out from the reflected spectrum. Whew a voltage is applied on the liquid crystal, the index of the liquid crystal will change, the surface plasmon resonance will change and the color of the reflected light will change. The experimental result is shown in Fig. ?, here the dots are experimental data and the solid curves are theoretical calculations, When a p-polarized white light was incident on this device at zero voltage, the surface plasmon resonance was at 640 nm, the red color was absorbed and the reflected light looked cyan. When a 1 ()-v voltage is applied, the resonance shifted to 56011111, green color was absorbed and reflected light looked magenta. When the voltage increased to 30-v, the surface plasmon resonance shifts to 450 nm, blue color was absorbed and the reflected light looked yellow. The experiment had shown good agreement with theory.

When a symmetric structure is used as shown Fig. 3, a very thin liquid crystal layer is sandwiched by two prisms with metal coatings on them, the surface plasmon wave generated at one side can be coupled to the other side, generate another surface plasmon wave, and]c-radiate the light with the same frequency. This is a bandpass filter. If a voltage is applied to change the index of the liquid crystal, the color of the bandpass filter can be tuned by the volts:',c,

Fig. 4 shows a theoretical calculation of the surface plasmon tunable bandpass filter. When the liquid crystal has an index change dn from zer 010 0.S, the transmission peak shifts from 450 nm to 650 nm.

Since surface plasmon is a surface effect, only a very thin liquid crystal layer is responsible to surface plasmon excitation. It has been reported that the switching time of surface plasmon in liquid crystal is two orders of magnitude faster than the switching time of bulk liquid crystal. For the sur face plasmon tunable notch filter, a switching time of 0.2 ms has been observed. For sur face plasmo n tunable bandpass filter, the switching time should be even faster.

Being a fast switching device, and able to generate field sequential red, green and blue colors, sur face plasmon tunable filler can be used for both projection and direct view display devices. For a single panel projection display, the surface plasmon tunable filter can be used to replace the color wheel to generate the field sequential red, green and blue colors to shine on either a liquid crystal display panel or a digital micro-mirror device to generate a color image.

The application) of surface plasmon tunable filter for a direct view display is shown in Fig. 5, white light from a linear lamp is collimated by the cylindrical lens, and is incident on a surface plasmon tunable filter; the tunable filter generates a field sequential I-cd, green and blue colors, then shines on the reflector, which changes the collimated light into a diffused light, and finally reaches a monochrome liquid crystal display panel, and this monochrome panel can show a full color image. Compare with the current color liquid crystal display device, this device has the advantages as: the number of pixels can be reduced to one third, no tiny color filters needed in each pixel, high aperture ratio since the pixel is now three times bigger, and reduce cost because he fabrication of a monochrome liquid crystal panel is much easier than a full color liquid crystal panel.

Reference:

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3. Yu Wang, Appl. Phys. Lett. 67, 27S9 (1 995).

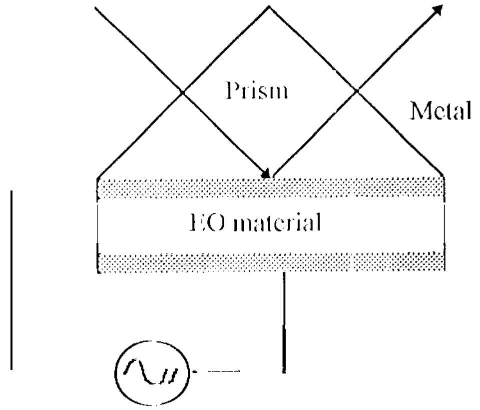

Fig. 1 Experimental setup of surface plasmon tunable color filter

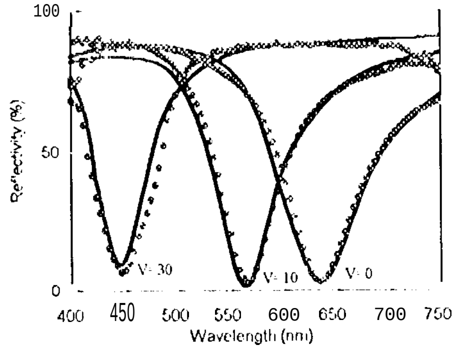

Fig. 2 Voltage-induced color selection with 50 nm silver film. When the applied voltage increases, the absorption band shifts toward lower wavelength

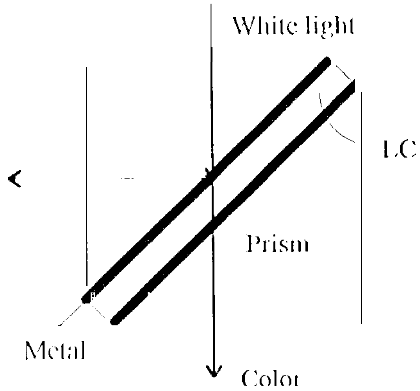

Fig. 3, Surface plasmon tunable band pass filter has a symmetric structure.

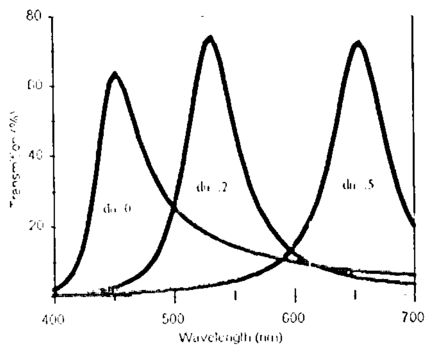

Fig 4 When the index of liquid crystal changes from 0 to 0.5, the maximum transmittion shifts from 450 nm (blue) to 650 nm (red)

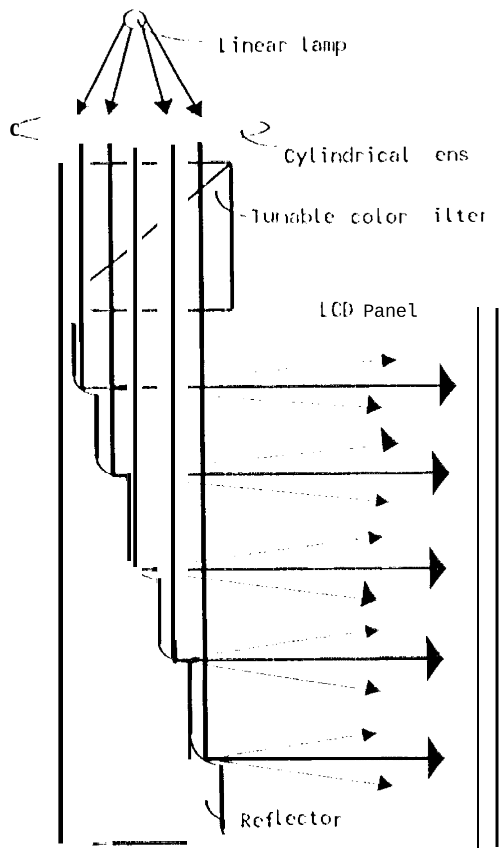

Fig.5 If a surface plasmon tunable filter is used, a monochrome liquid crystal display panel will be able to generate a color image